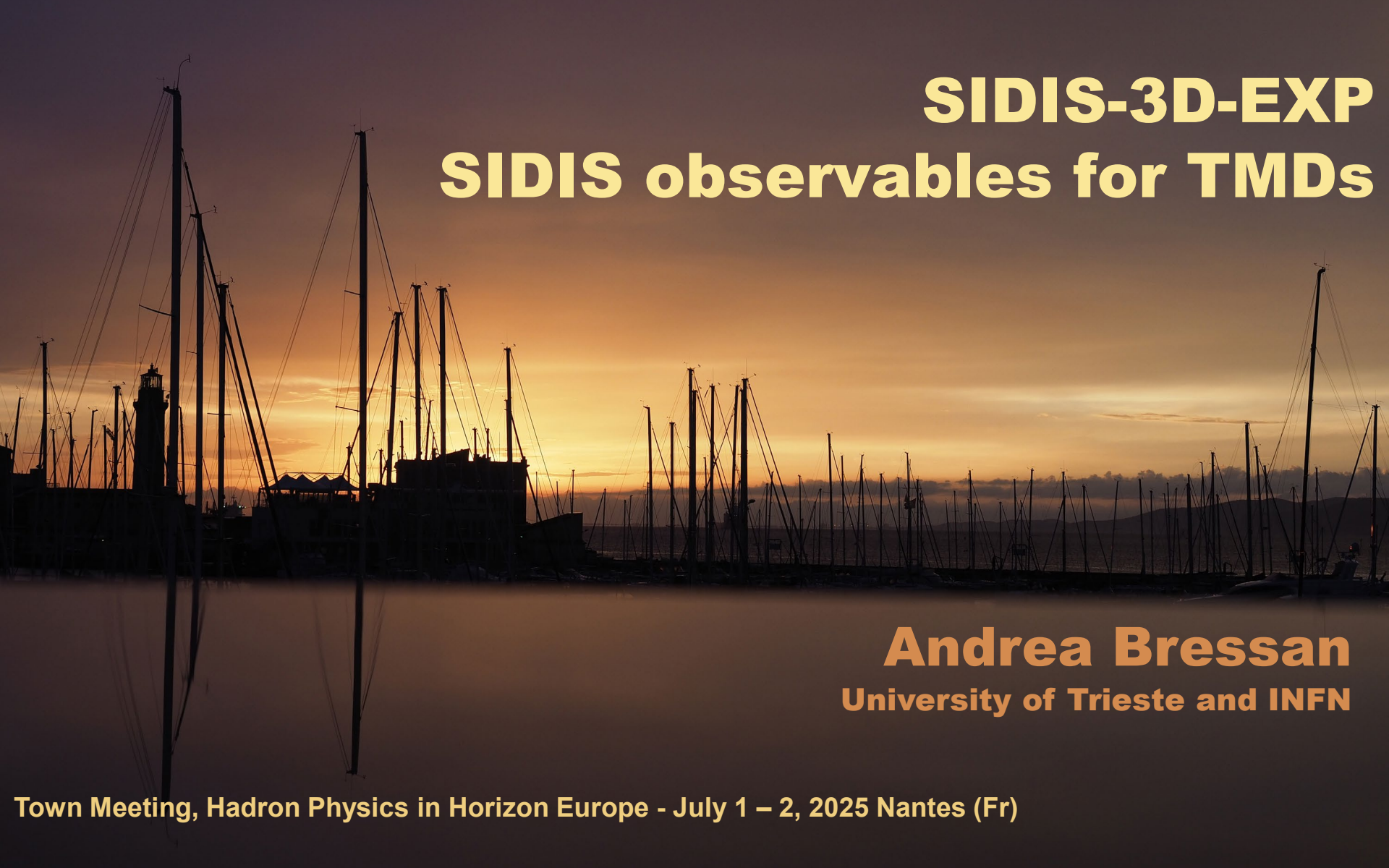


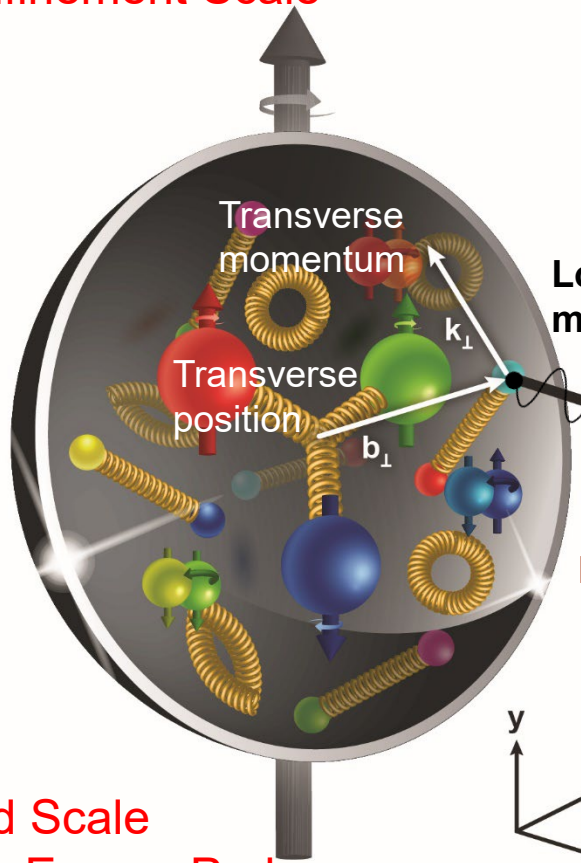
SIDIS-3D-EXP
SIDIS observables for TMDs

Andrea Bressan
University of Trieste and INFN

Town Meeting, Hadron Physics in Horizon Europe - July 1 – 2, 2025 Nantes (Fr)

Transverse structure of the Nucleon

Confinement Scale



Longitudinal momentum

xP

Photon Virtuality Q^2

ℓ'

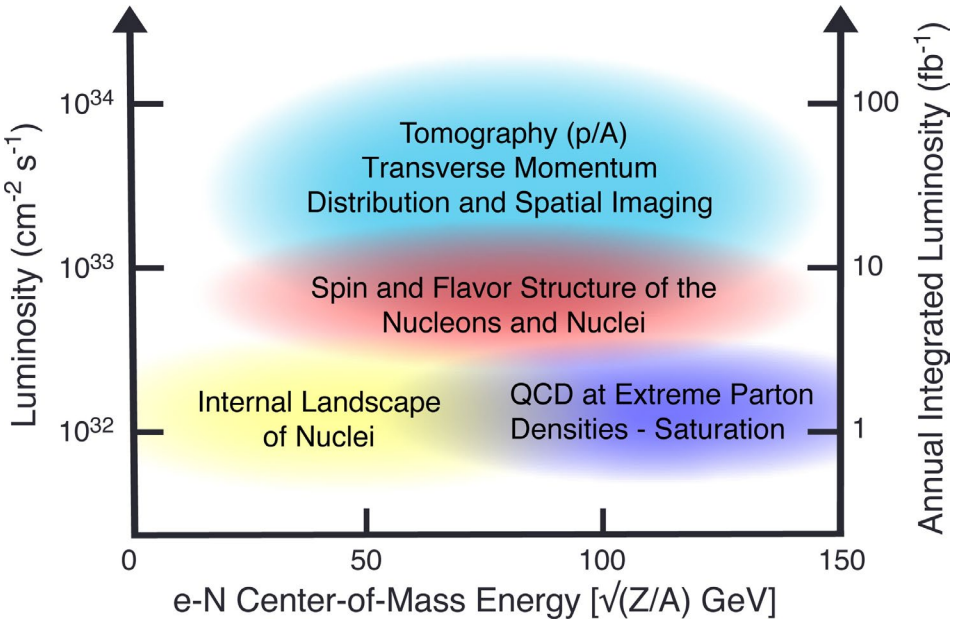
ℓ

$$W_p^q(x, \vec{k}_\perp, \vec{b}_T)$$

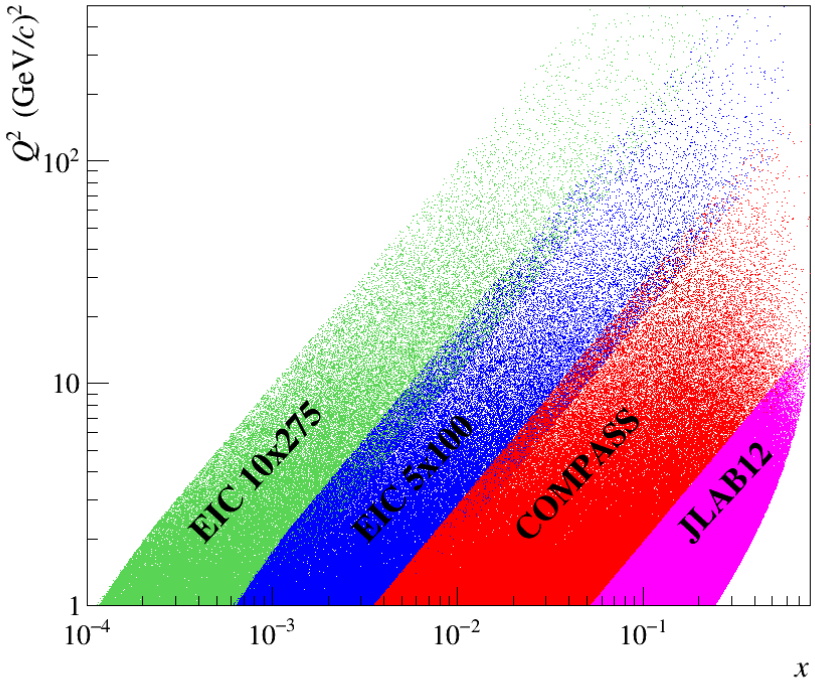
Hard Scale
High Energy Probe

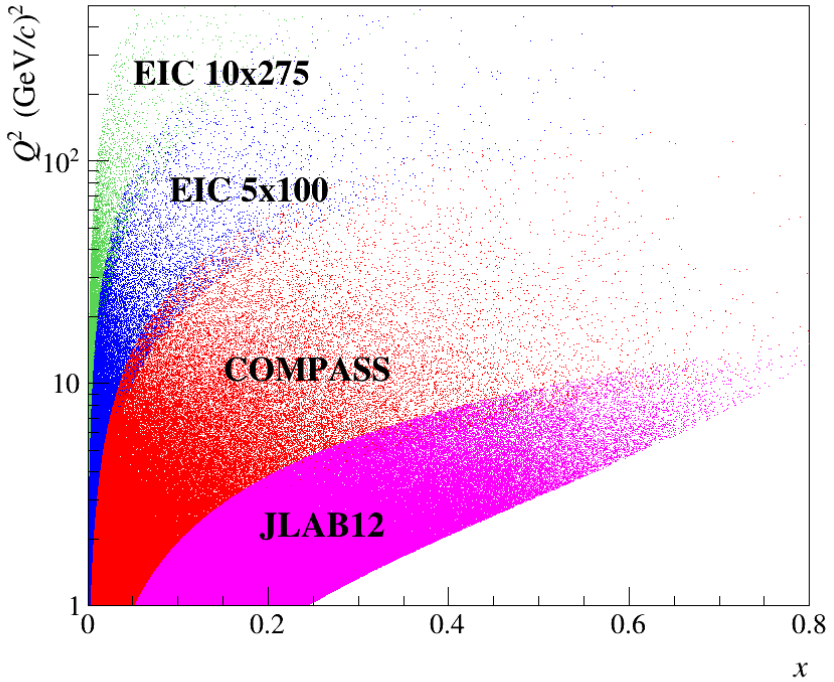
A future sherif in town

- Semi-inclusive deep inelastic scattering is the **“golden channel”** for the study of the internal structure of the hadrons (p, D, PID for flavor separation)
- The first polarized eA collider with variable center-of-mass energy, outstanding luminosity, … i.e. the EIC is coming, and it will start be operational in about 10 year



The phase space





The TEAM for SIDIS-3D-EXP

- **Experimentalists:** expert in the field are collaborating in the future ePIC experiment @ EIC and members either of COMPASS or CLAS12
  - INFN (Ferrara, Frascati, Torino, Trieste), Charles University (Prague), National Centre for Nuclear Research (Warsaw), IRFU(Saclay)
- **Phenomenologists:** leaders in the extraction of TMD PDFs and FFs from global analysis
  - INFN (Pavia, Torino)
- Together with the **partner institutions** in JLab and Yerevan
- We plan for a coordinated efforts aimed to improve the mapping of TMDs and more specifically the **u** and **d** quarks, in a 3D momentum space

In mode detail:

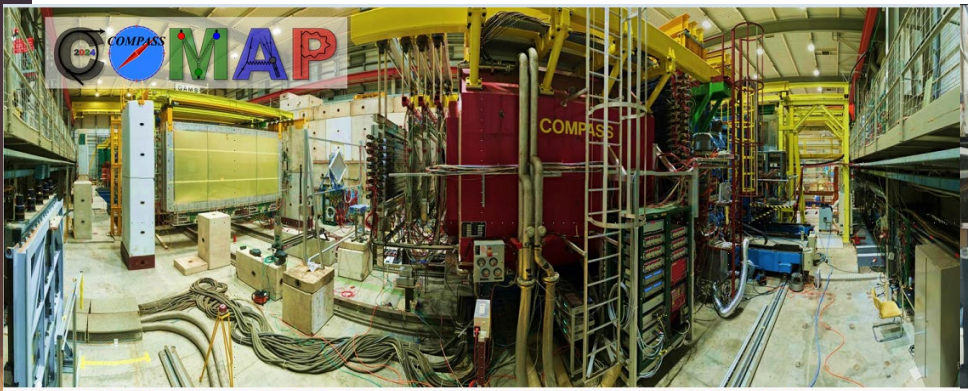
SIDIS-3D-EXP wish to:

- Construct **COMMON ANALYSIS TOOLS** to improve the treatment of diffractive **vector mesons contaminations, higher twists and radiative electro-magnetic effects in SIDIS**.
- Improve the knowledge of **d-quark TMDs and transversity and** get a deeper insight in the Collins fragmentation function by further developing the $^3P_0$ **fragmentation model**.
- Pave the way for **precise simulations** of combined **SDME and TMD effects at the ePIC experiment at EIC**.
- Fully exploit the **large statistics** collected by COMPASS with 160 GeV longitudinally polarized muons and transversely polarized targets (10^8 hadrons on p and D); **intermediate x-region** of TMD PDFs
- Use the data collected by CLAS12 with longitudinally polarized beams and targets and collect first transversely polarized data to extract information on the mostly unknown **valence region** of TMD PDFs

Facts we need to emphasis

- The **full year of deuteron data** collected by COMPASS in 2022, as well as those collected in 2010 with protons will very likely remain **unique for the next decade**.
- CLAS12 is preparing for collecting **transversely polarized data before 2030**.
- There is a **strong need to form young scientists** capable of dealing with the future challenges posed by EIC high precision analysis
- Europe has a leading role in the field of TMDs, and we have developed strong collaboration between experimentalists and theoreticians.
- All the knowledge acquired will be made available in the **Virtual Access** facility **3D Portal**.
- The WP will use **TSA at CERN** and eventually **BNL** for data analysis and simulation, meetings and workshops organized by the participants.

Very real tasks



10th COMPASS Analysis Phase international mini-workshop (COMAP-X); Radiative Corrections in SIDIS: COMPASS - JLab

November 21, 2024
CERN
Europe/Zurich timezone

Enter your search term

Overview
Timetable
Contribution List
Videoconference

Contribution List

8 / 8 Enter #id or search string

1. Introduction
Dr Bakur Parsamyan (AANL, Turin section of INFN and CERN)
11/21/24, 2:00 PM

2. Radiative Corrections: COMPASS experience - General intro and Multiplicities
Prof. Andrea Bressan (Universita e INFN Trieste (IT))
11/21/24, 2:10 PM

4. Radiative Corrections: COMPASS experience - Azimuthal Asymmetries
Jan Matousek (Charles University (CZ)), Vendula Benesova (Charles University (CZ))
11/21/24, 2:40 PM

5. Radiative Corrections to SIDIS: Current Status and Perspectives
Igor Akushevich
11/21/24, 3:05 PM

3. Evaluation of Radiative Corrections in Inclusive Proton Production with CLAS12
Prof. Fatiha Benmokhtar
11/21/24, 3:35 PM

7. Radiative Corrections: JLab experience
Harut Avakian, Timothy Barton Hayward (University of Connecticut (US))
11/21/24, 3:55 PM

12th COMPASS Analysis Phase international mini-workshop (COMAP-XII

April 30, 2025
CERN
Europe/Zurich timezone

Enter your search term

Overview
Timetable
Contribution List
Videoconference

Contribution List

4 / 4 Enter #id or search string

1. Introduction
Dr Bakur Parsamyan (AANL, Turin section of INFN and CERN)
4/30/25, 2:00 PM

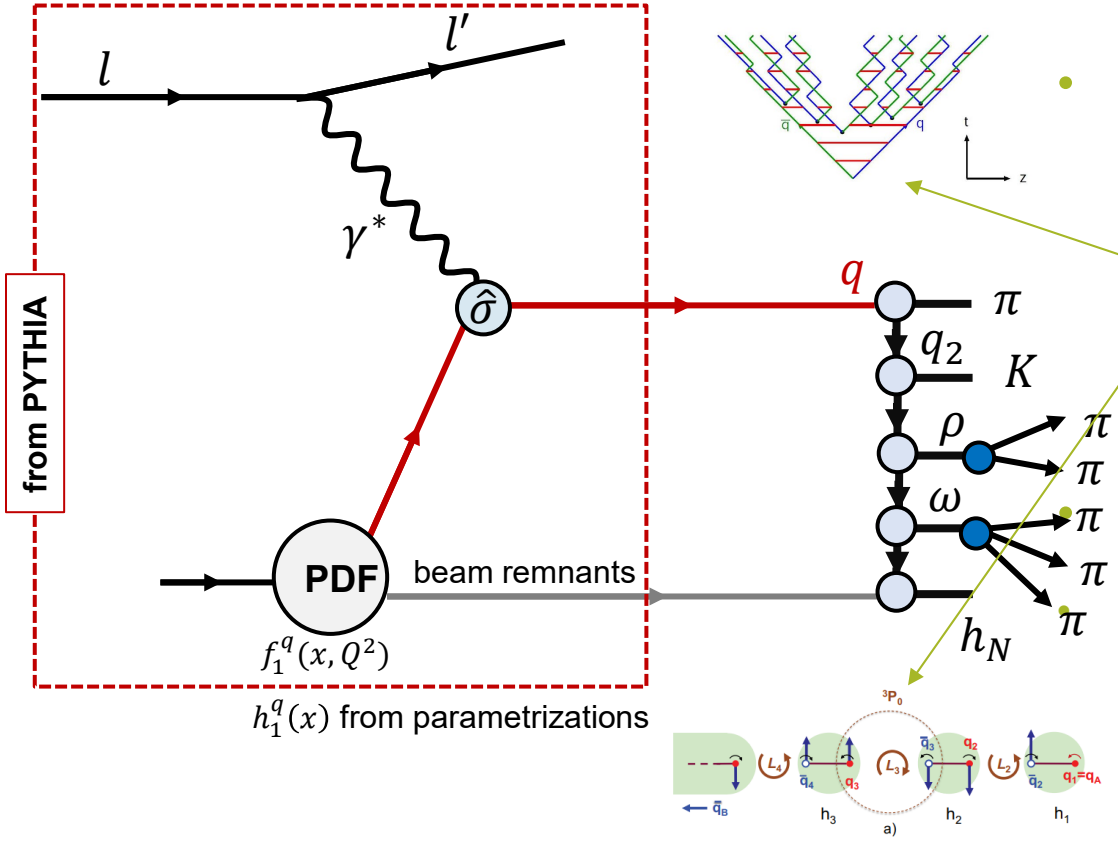
3. The role of diffractively produced VMs: COMPASS experience
Anna Martin (Trieste University and INFN (IT))
4/30/25, 2:10 PM

2. The role of diffractively produced VMs: JLab experience
Harut Avakian
4/30/25, 2:40 PM

7. Studies of longitudinal and transverse rho acceptances using the PYTHIA
Christopher Dilks (Thomas Jefferson National Accelerator Facility)
4/30/25, 3:10 PM

StringSpinner: polarized quarks in PYTHIA

StringSpinner *[Kerbizi, Lönnblad, CPC 272 (2022) 108234]*



- The recursive string+$^3P_0$ model of hadronization
- *«elementary splitting»* described by a splitting amplitude based on:
  - The Lund String Model
  - The $^3P_0$ mechanism

$$^3P_0 \equiv {}^{2(s_1+s_2)+1}L_{J=L+S=0}$$

Is the vacuum quantum number.

Budget

- Budget is:
  - 90% for contract for hiring co-funded PostDocs (50% sharing)
  - 10% for travels and meetings
- We need a group of people that can dedicate large fraction of their time to do these cross-experiments cross-theory-groups activities
- In person meetings will be mandatory for planning and monitor progress

Details of the proposed tasks

Task1: SSA/wTSA Analysis of COMPASS data (INFN-TS-TO, CU):

- Multi dimensional measurements of TSA and wTSA on deuteron and proton

Task2: Unpolarized cross sections Analysis of COMPASS data: (INFN-TS, CU, NCNR)

- Endeavor to understand the flavor-dependence of the partonic transverse momentum and the Boer-Mulders function.
- Explore the use of new tools for measuring single and hadron pair production.

Task3: Unpolarized cross sections and SSA Analysis of CLAS12 data (INFN-FE, INFN-LNS)

- Multi dimensional measurements with enhanced sensitivity to the valence

Task4: Run preparation for CLAS12 transversely polarized data (INFN-FE, INFN-LNS)

- Design of the best experimental configuration and impact study

Task5: Theory support (INFN-PV, INFN-BO)

- Interpretation of the new data including effect of VM and higher twist
- Impact studies of new data, preparation for future measurements

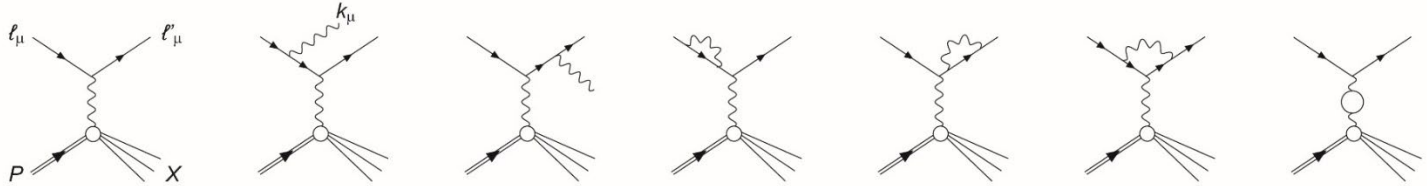
Task6: General and common effort to (all participating institutions):

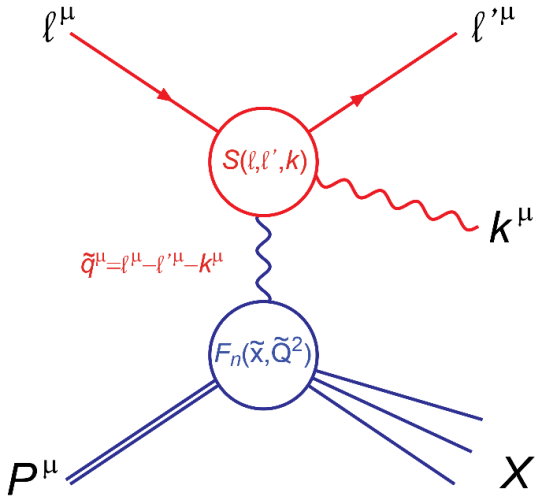
- Develop common analysis tools and chains for COMPASS and CLAS12 to investigate deeply their dependence
- Develop and test GPU-based algorithms for the analysis of SIDIS observables.
- Develop and use of MC event generators with TMD PDFs and spin effects in the fragmentation with String-Spinner developments.
- Perform impact studies via full simulations and reconstructions using the software stack that is presently developed by the ePIC collaboration at the EIC.


Thank you

LEPTONIC RADIATION

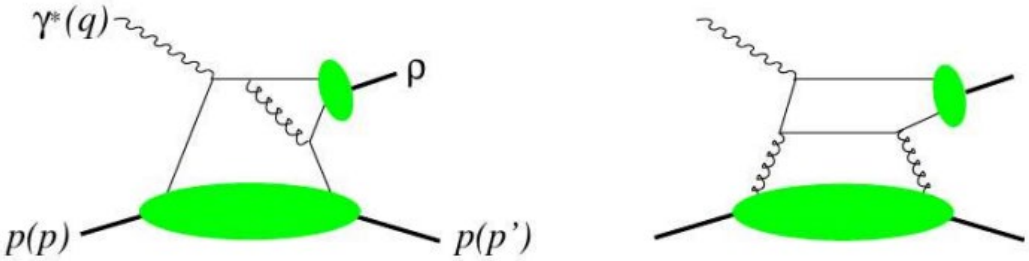
Feynman diagrams for leptonic radiation





- The radiative leptonic tensor $S(\ell, \ell', k)$, include Born + loops at $\mathcal{O}(\alpha_{em}^2)$:
  - Gauge invariant
  - Infrared finite
  - Universal (for 1γ exchange)
  - The kinematic is shifted $\tilde{q}^\mu = q^\mu - k^\mu$

Example: background from exclusive VMs



- Contributions from ρ^0, ω and ϕ
- Exclusive ρ^0 leptoproduction can be viewed as a virtual photon fluctuation into a $q\bar{q}$-pair followed by the scattering of this pair off the nucleon and formation of the final state.
- These are spin-1 objects, i.e. $J = 1$. Decay particles have spin 0, so $L = 1$ for the decay. In words when the VM decays, its spin-state will be reflected in the orbital momentum of the decay particles.
- Due to the nature of the process, we can reject some/most, not all, of these hadrons from our sample

- Exclusive VMs can be removed from the sample when both final hadrons detected (VISIBLE PART). **EVM cut**:

$$z_t = z_{h^+} + z_{h^-} < 0.95$$

- If one hadron is miss, this is no longer true (INVISIBLE PART).
- Strategy:
  - have a MC for exclusive VMs with Spin Density Matrix Elements.
  - Compare MC with our exclusive data normalize MCs
  - Use this normalization to subtract the invisible fraction from our data. **EVM subtraction**

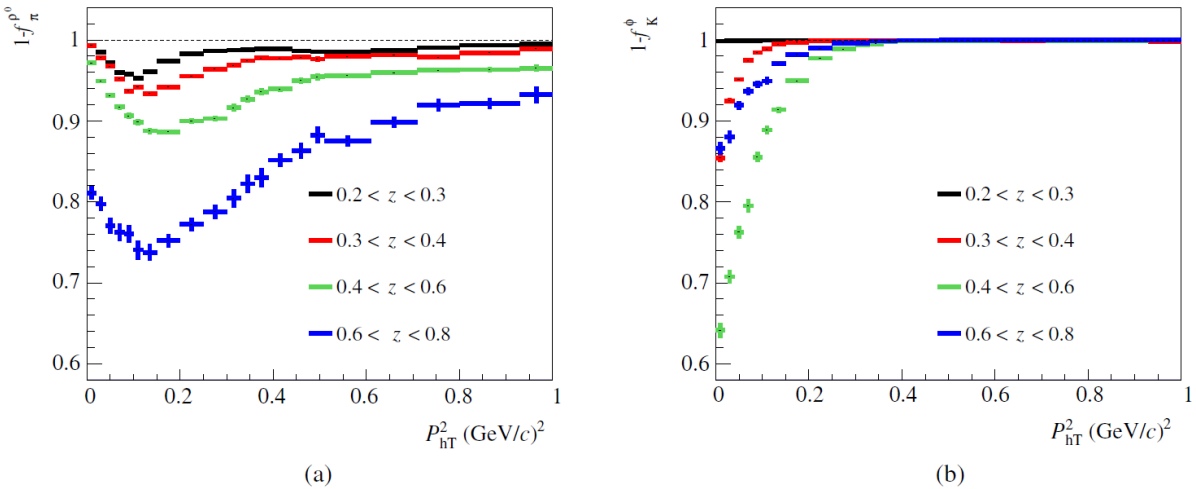
2nd publication on P_{hT} distributions (2018);

Improved binning

TABLE I. Bin limits for the four-dimensional binning in x, Q^2, z and P_{hT}^2.

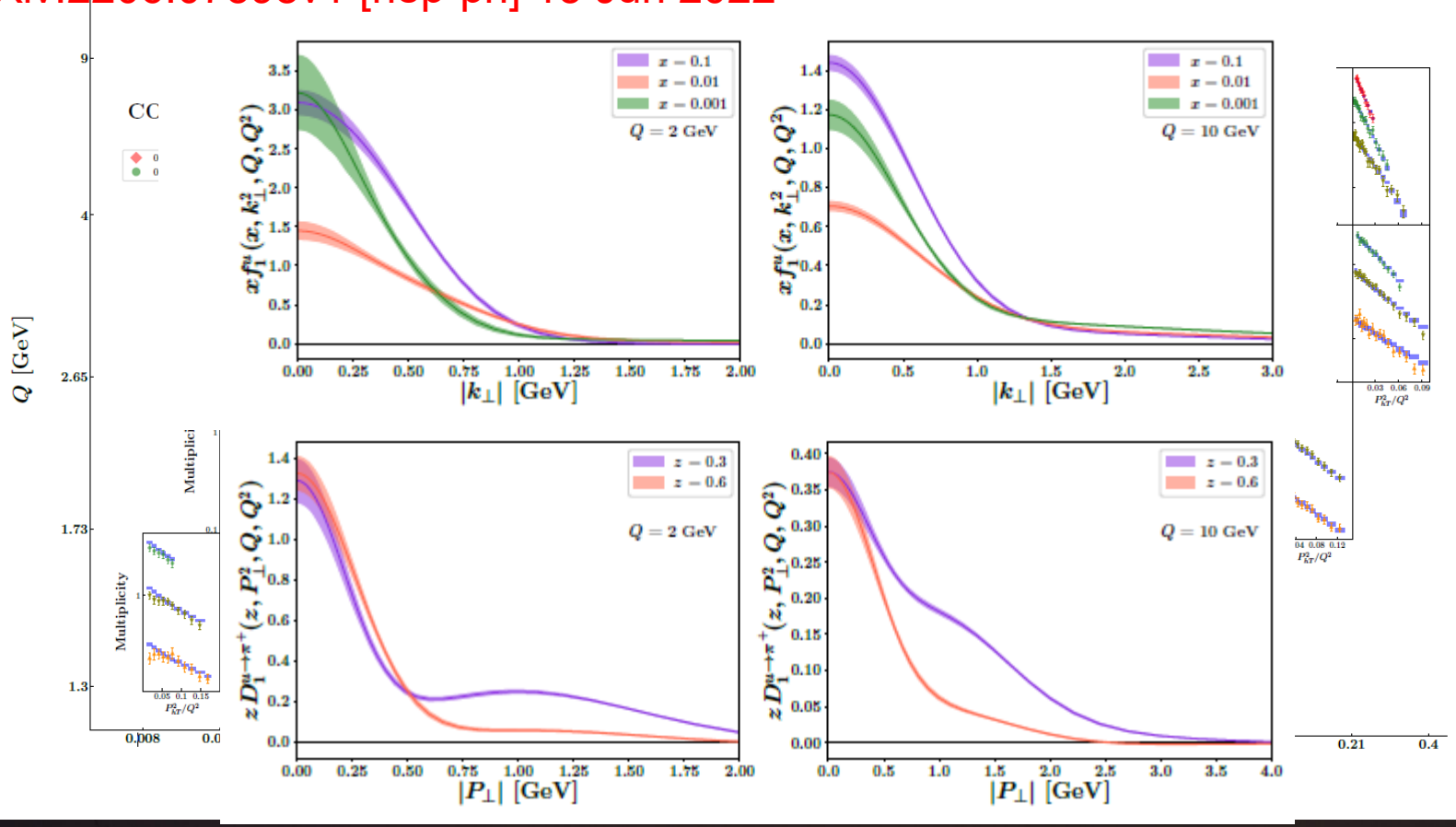
	Bin limits								
x	0.003	0.008	0.013	0.02	0.032	0.055	0.1	0.21	0.4
Q^2 (GeV/c)^2	1.0	1.7	3.0	7.0	16	81			
z	0.2	0.3	0.4	0.6	0.8				
P_{hT}^2 (GeV/c)^2	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.17	0.196
	0.23	0.27	0.30	0.35	0.40	0.46	0.52	0.60	0.68
	0.76	0.87	1.00	1.12	1.24	1.38	1.52	1.68	1.85
	2.05	2.35	2.65	3.00					

Subtraction of Diffractive Vector Mesons

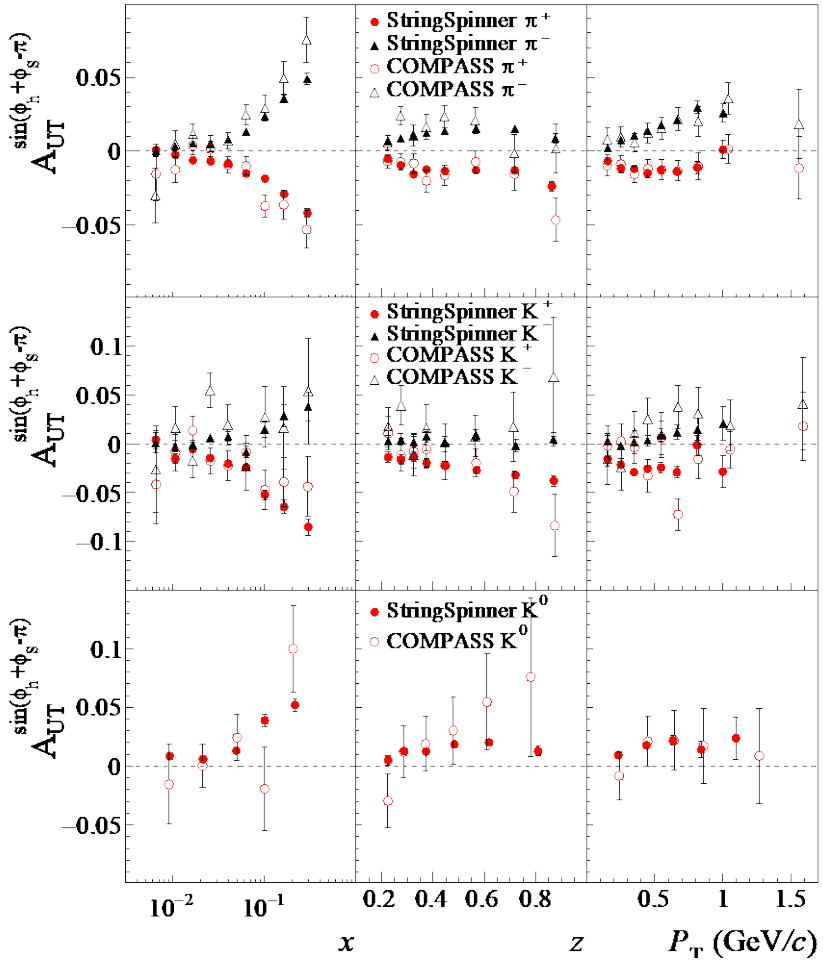


Phenomenological fits

arXiv:2206.07598v1 [hep-ph] 15 Jun 2022

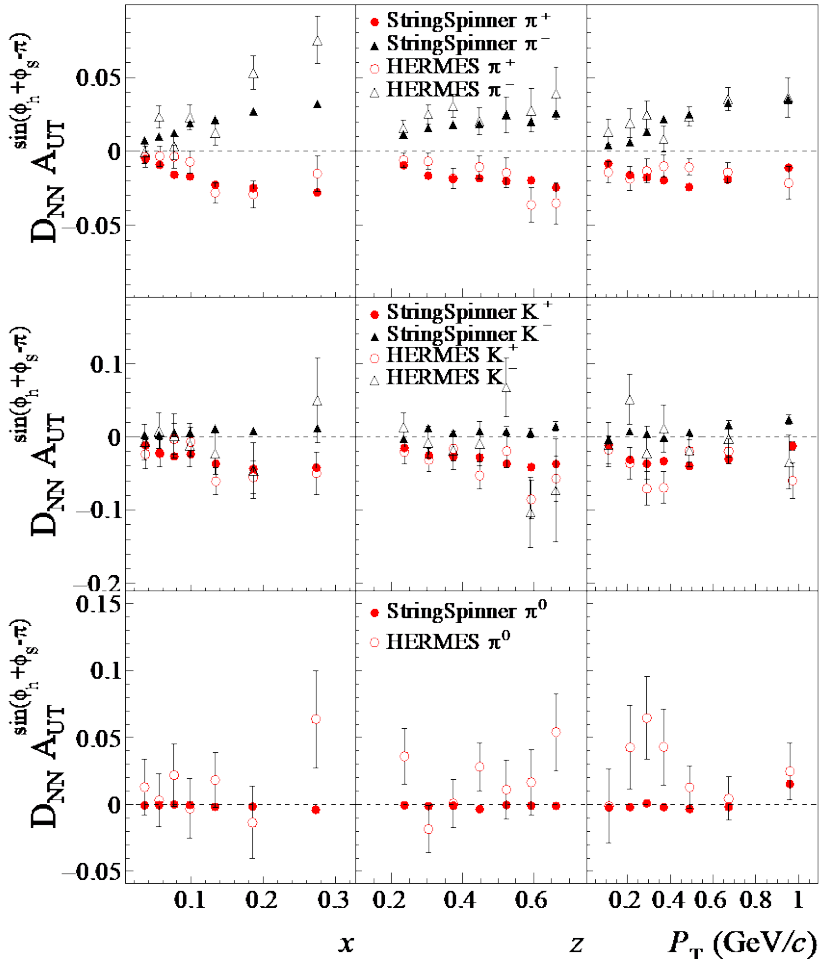


Collins asymmetries for π and K @ COMPASS



Satisfactory description also for kaons

Collins asymmetries for π and K @ HERMES



Smaller π^- asymmetries for x>0.2 in simulations

π^0 in simulations as expected by isospin

Dihadron asymmetries